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CRYSTAL PALACE BAND II TESTS: comparison of transmitted polarizations.

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CRYSTAL PALACE BAND II TESTS: COMPARISON OF TRANSMITTED POLARIZATIONS

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Summary

A description is given of an experiment conducted in the London area, with a test transmitter at Crystal Palace, to examine the relative merits of different polarizations for Band II f.m. radio broadcasts. The tests allowed for reception at roof-top level, in cars, and on portables. The relative amounts of multipath were assessed. It is concluded that in heavily built up areas, as well as in other types of area, there is a significant advantage for car radios and portables in transmitting a vertical component. If this is added to a present horizontally polarized transmission with equal power (3 dB more transmitter power) the effective increase in signal for these receivers is 5 to 7 dB, while stereo reception on fixed horizontal aerials is not significantly affected.

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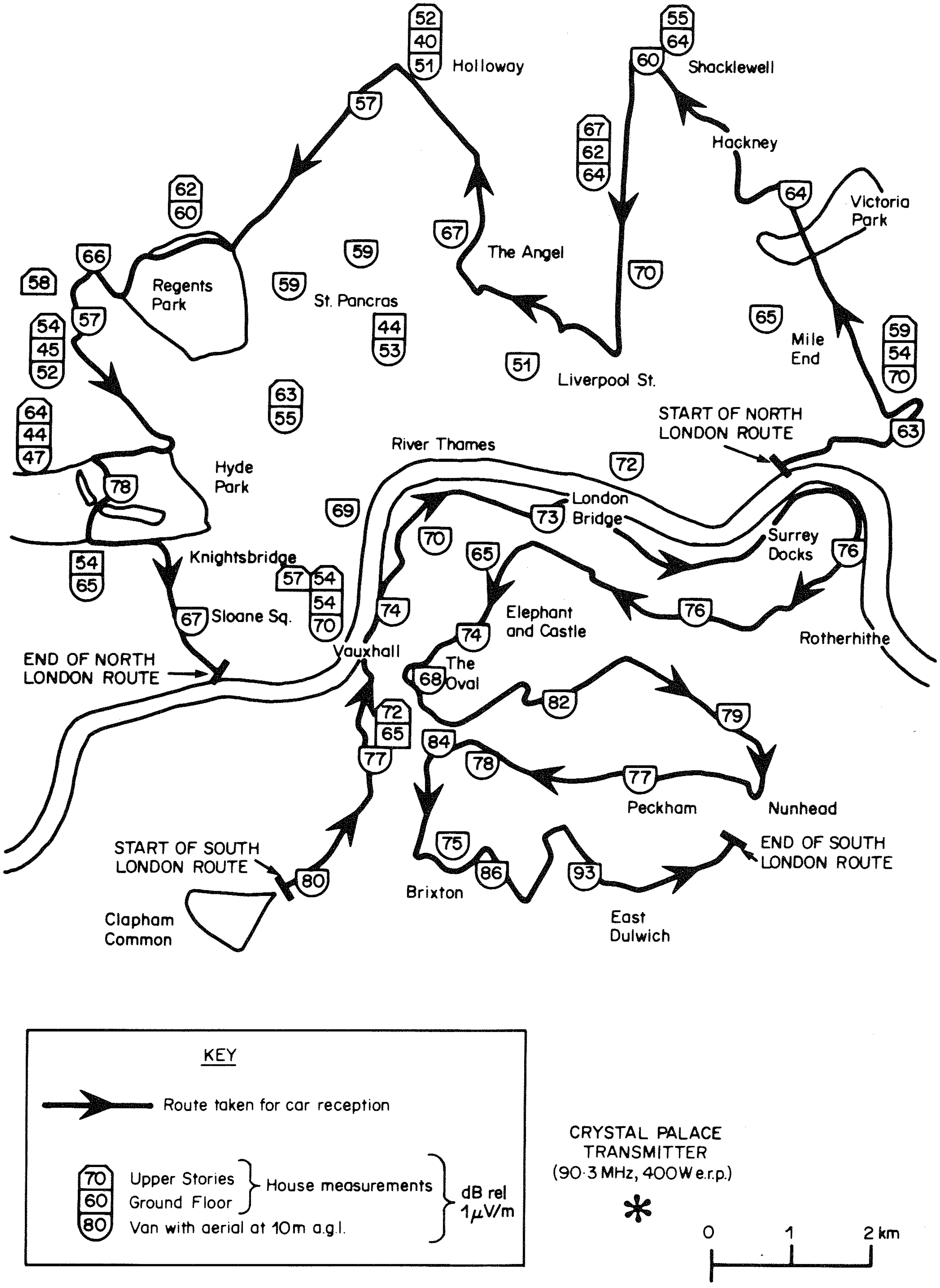

Fig. 1 - Measurement route and locations for Band II polarization experiment

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1. Introduction

When the v.h.f. f.m. service was first introduced it was assumed that reception would be via a fixed aerial at roof top level. For this purpose horizontal polarization was chosen. Today, when other forms of reception are also important (e.g. in cars and on portable sets), the choice must be reviewed. Several experiments[1,2,3] have been conducted to determine the relative merits of different forms of polarization for Band II broadcasts. The problem has so many aspects, it was felt that further experimentation was necessary particularly concentrating on reception in built-up areas.

This report describes an experiment conducted in London, where comparisons were made for reception with

a) directional roof aerials,
b) aerials built-in to portable receivers, indoors, and
c) car mounted aerials.

The project was designed to show which transmitter polarization gives

i) the largest median signal strength for receivers with typical aerials, and
ii) the least multipath.

Other factors will influence planning, such as the cost of transmitting aerials and the investment in existing systems. Some reference to these factors is made in the conclusions.

2. The test transmitter

Details of the test transmission are:

Location: Crystal Palace (TQ 339712).
Site Height: 110 m a.o.d.
Frequency: 90.3 MHz.
Modulation: Radio 3 (rebroadcast of Wrotham) or a sawtooth waveform of 130 Hz. Both with inserts announcing that transmissions were for test purposes.
Tx power: 250 watts.
Feeder loss: 2.7 dB.
Aerials: Type: Wideband 4-element
Arrangements: Two units: one horizontal, one vertical.
Gain: ~5 dB with max. at 345° ETN.
Height: ~170 m a.g.l.
Effective radiated power (e.r.p.): ~400 W.
Feeds to:
1. Horizontal aerial.
2. Vertical aerial.
3. Both via splitter.
4. Both via splitter and 90° phase shift in one arm.

Polarization:
1. Horizontal.
2. Vertical.
3. One slant direction.
4. Either circular (one only used)

Notes:
1. The omission of one form of slant and one of circular is irrelevant because conclusions should not be sense dependent.
2. The total e.r.p. (i.e. the sum of vertical and horizontal e.r.p.'s) is the same for all polarization states.

3. Area covered by tests

The northern boundary of the test area was restricted by signal-to-noise ratio. The other boundaries were restricted by purity of polarization. The impurity existed because the two transmitting aerials used were separated vertically by about 3 m and had E-plane patterns different from those of the H-plane. Despite the restrictions the test area covered a large part of Greater London as shown in Fig. 1.

4. Reception in cars

Our equipment for car reception tests included a 0.8 m monopole with a magnetic mount, so that we could experiment with positioning. Most car aerials are vertical monopoles, but a single position on a car cannot be taken as representative. A digital receiver[4] measured field strengths con-

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tinuously when the car was on the move, and a signal analyser[5] recorded the statistics of signal variations.

Sources of error are summarized below.

i) The receiver suffered from temperature drift and other effects which, unless repeated calibration was made, could introduce errors of about 2 dB.

ii) The field at any one location can be disturbed in a way unique to that location; thus, to obtain representative results, many measurements must be taken.

iii) The car/aerial combination does not give an omnidirectional receiving pattern, so results depend on orientation of car, relative to the propagation path.

iv) The transmitter output had some variation.

The combined effect of these errors may not be considered serious for the determination of a service area, but care must be taken to detect small differences between transmitter polarizations.

The method employed was to take measurements for the whole route with the aerial at the centre of the car roof. We then concentrated on a part of this route and tried several receiving aerial positions, extra attention being paid to receiver sensitivity and transmitter output to obtain relative values for the various polarizations.

Fig. 2 gives the results of field strength measurements for the whole route with a vertically polarized transmission and the receiving aerial at the centre of the car roof. These results are analysed in ½ km stretches: the points give median field values and the lines give the interdecile range of signal variability. Place names are written on Fig. 2, so that the measurements may be related to positions on the map of Fig. 1. Thus, from these figures it can be seen how well the transmitter provides car reception in the area and the kind of variability that is experienced.

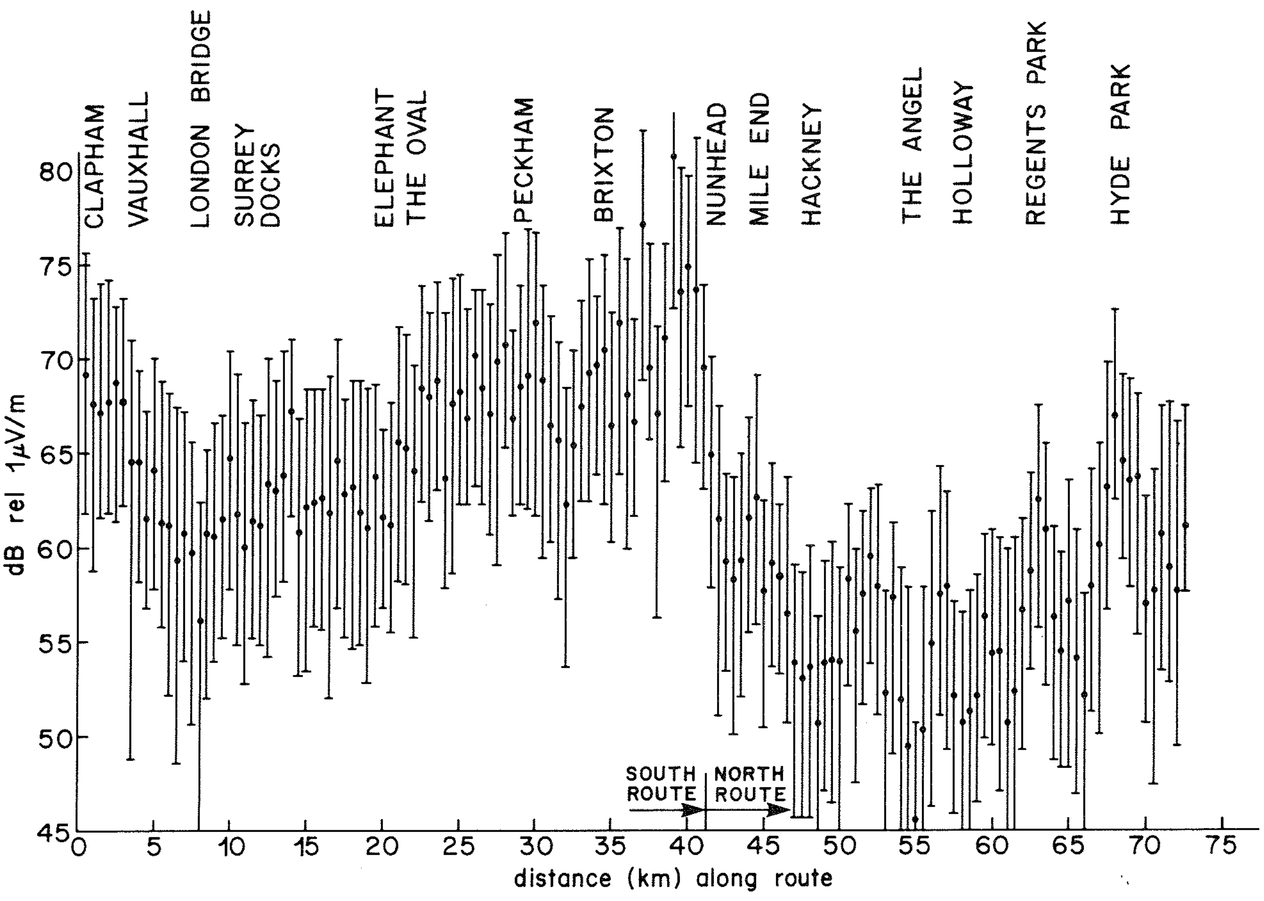

Fig. 2 - Field strengths along route, with vertically polarized transmission: (vertical receiving aerial at centre of car roof) Median points with lines showing interdecile range

TABLE 1

Relative merits (dB) of transmitter polarizations for different receiver aerial positions on a car

Receiving aerial on car	Transmitted polarization (same total power)		
	Horizontal	Vertical	Slant
Centre of roof	0	7	5
Front nearside wing	1	7	5
Front of roof slanting	1	5	1
Front of roof vertical	0	4	5

The many factors involved make it difficult to give a quantitative answer to the question: how much better is one transmitter polarization state than another? However, let us say that an area is served if 90% of locations in it receive an adequate signal. Then, for each ½ km stretch of road, we can analyse the measurements to find the difference in transmitter power required to give parity in this criterion. The average of these differences gives a figure for the relative merits of transmitter polarizations.

Our work indicates that for car reception the difference between slant and circular transmission is small. However, both vertical and mixed polarizations (slant or circular) give advantages over horizontal, dependent on the aerial position on the car. These relative advantages are shown in Table 1.

It is of interest to note that the aerial at the centre of the roof gives results similar to the more widely used rod aerial on the front wing.

Of the car aerial positions tried the centre of the roof gives the nearest approximation to a monopole on a ground plane. Thus, we might expect it to discriminate most strongly against horizontal transmissions. Beyond this it is difficult to explain fully the results in Table 1, because the mechanisms involved are intangible.

i) The field incident on the car is distorted by scatter components etc. (particularly in built-up areas).

ii) The currents in the car body will interact, and affect the signal picked up in the aerial.

iii) The variation of field with height will not be as theory, based on simple geometry, predicts.

Investigations of the horizontal radiation pattern of the receiving aerial were made with the car on a turntable. When receiving horizontal transmissions a most irregular pattern was obtained with variations greater than 30 dB, dependent on frequency and exact location of the aerial on the car. This investigation was made in a fairly open location; in built-up areas the deep nulls will be partly filled by the reception of a scattered field.

The conclusions concerning the advantage of vertical or mixed transmissions for car reception may be invalid for non-metallic car bodies (which may become more prevalent), or if a better aerial were developed for reception of horizontal transmissions. However, a ferrite rod aerial, in its present state of development, does not change the conclusion because investigations have shown[6] that it could not compete with the monopole. Therefore, a vertical rod (with a counterpoise if needed) is likely to be the preferred form, even for non-metallic car bodies.

5. Reception at 10 metres

Measurements were taken with a two-element yagi raised to 10 m above a van, by pneumatic mast. A mechanism allowed the aerial to be held in either the horizontal or vertical position. The different transmitter polarizations were examined by noting:

i) signal strengths,

ii) field variations over a small movement of the van, and

iii) multipath.

This phase of the project should be representative of domestic reception with a good roof aerial.

5.1. Signal strength and variations

Fig. 1 shows the test points chosen for this part of the experiment, together with a number characterizing the field strengths at these locations. A single number is sufficient to represent the fields at one location because no significant dependence on polarization was found, i.e. the average field over small van movements was similar, provided the receiving aerial had the same polarization as the transmitting aerial. Circular or slant polarized transmissions of the same total power, when received indiscriminately on vertical or horizontal dipoles, had the expected reduction in field (relative to the values on Fig. 1) of about 3 dB. If a discriminating choice between horizontal and vertical is made this average loss becomes 1.5 dB. Thus, if circular or slant transmissions are used these reductions should be taken into account, because it is unlikely that receiving aerials will be correctly tilted and even less likely that circularly polarized receiving aerials will be used.

Measurements were taken to see how much vertical component of field was introduced by the propagation path when transmitting with horizontal polarization, and vice versa. It was found that in many cases so little cross-polar component was introduced by the propagation path that the limiting factor was the alignment of the receiving aerial. Even in the worst case the polarization discrimination was 4.5 dB.

5.2. Multipath effects

Degradation of f.m. signals by multipath propagation is dependent upon:

i) time delay of echoes relative to the main signal,

ii) the relative amplitudes,

iii) phase differences,

and
iv) how many echoes exist.

These factors should be known for each polarization. It is then necessary to be able to relate the above factors to the amount of degradation; such a relationship can only be determined by subjective tests. A paper by Harvey[7] gives such a relationship for mono, but we wish to consider stereo. A limited subjective experiment was conducted where, for stereo, a given echo caused more degradation than indicated in Harvey's paper for mono. A more extensive project is desirable to establish the multipath degradation of stereo.

Our investigations consisted of modulating the transmitter with a sawtooth waveform at a repetition frequency of 130 Hz and determining the extent of the multipath by observing the waveform on the display unit of the receiver described in Reference 4. In addition variations in signal were observed when the van was moved over small distances, because multipath would manifest itself in the amount of this variation. These investigations were done for horizontal to horizontal and vertical to vertical transmission. The conclusion reached was that a vertical transmission suffers from multipath only slightly more than horizontal. This is despite the fact that horizontally polarized receiving aerials have good rejection of signals end-on to the dipole elements. As we are assuming that listeners will use either vertical or horizontal plane polarized aerials, the conclusion of only slight difference in multipath holds good for mixed polarizations. However, it is possible that, should the correct circular/slant receiving aerial be used, multipath problems might be reduced because some reflections of a mixed transmission could produce signals of the opposite hand which will be rejected by the receiving aerial.

6. Reception in buildings

Measurements of field, field variations and multipath were made in buildings by exploring a chosen volume (approx. 2 m x 2 m by 1 m high) with a short (53 cm) dipole. It might be thought that obstructions would so distort the polarizations that the original plane would be undetectable, but we found that on average the field in the orthogonal plane was less by about 5 dB.

No significant polarization dependent difference was found in the median field strength provided the correctly polarized receiving aerial was employed. Near the ground but away from walls there is a tendency for a larger vertical component of field to exist but this is compensated by a larger horizontal field near walls and away from the floor. The largest field obtainable within the chosen volume was noted for each polarization separately. The values plotted in Fig. 1 are the averages of these maxima.

As with reception at 10 m above ground outside, it was found that multipath propagation would produce only slightly more degradation of quality for vertically polarized transmissions.

From these results it should not be inferred that it is unimportant which polarization is transmitted, because the way an aerial on a portable set is used must be considered. Most people just draw out the aerial and leave it vertical. In any case if placed horizontally the aerial needs to be very carefully arranged to obtain the best results. On the basis of the use of vertical rods it is concluded that portable receivers in the home will be better off in signal level by about 5 dB for vertical transmission relative to horizontal. For mixed polarization this relative improvement was measured to be in the region of 3 to 4 dB. These comparisons are for the same total transmitter power.

7. Relationship between receiving installation types

The results of the experiments give an idea of how service area limits might differ for different types of receiving installation and for different polarizations. This comparison should allow for the respective:

a) statistics of the field strengths in the volumes occupied by typical aerials;

b) voltages supplied to receiver terminals by typical aerials for a given incident field (including dependence on transmitted polarization), and

c) voltages required for good listening on typical sets.

Table 2 relates other forms of receiving installation to a 10 m aerial receiving stereo from a horizontal transmission. It is based on the assumption that the *total* transmitted power is the same in each case. The columns headed 'a', 'b' and 'c' give 'scores' in dB for the reasons 'a', 'b' and 'c' given above. Column 'a' is based on a comparison of 90% of a car route receiving a good signal, with a similar criterion for the other receivers (except that in the latter cases some allowance is made for the fact that limited positional adjustment away from bad reception points is possible). Column 'b' allows for the type of aerials in use and the way in which they are used, e.g. portables with vertical rod aerials. Column 'c' is based on a rough assessment of typical relative sensitivities, from a wide variety of different receivers. The overall score (a + b + c) shows that relative to fixed stereo installations cars and portables have considerably

TABLE 2

Comparison of receiving installation types

Condition		dB for reason:			
Transmitter Polarization	Receiving System	a*	b*	c*	Overall Score
H V C S	2-element aerial at 10 m (stereo)	0 0 0 0	0 0 −3 −3	0 0 0 0	0 0 −3 −3
H V C S	Car (mono)	−13 −13 −13 −13	−15 −9 −11 −11	20 20 20 20	−8 −2 −4 −4
H V C S	Portable, ground floor (mono)	−14 −14 −14 −14	−12 −7 −8 −8	20 20 20 20	−6 −1 −2 −2

* see text for explanation

H = Horizontal
V = Vertical
C = Circular
S = Slant

reduced service areas with the present horizontal transmissions, but if mixed polarization is used the service areas are comparable.

8. Conclusions

The project has shown the relative merits of different polarizations for transmissions in Band II with different types of receiving installation in a built-up area. The assessments quoted are based on a comparison of average values over many samples, but the variations experienced show that at any one location these assessments may be invalid.

The advantages and disadvantages of different polarizations relative to horizontal polarization are as follows (assuming the same *total* effective radiated power from the transmitter).

Vertical:
1. Better for car radios
2. Better and more convenient for portables.
3. Slightly greater multipath effects.
4. Existing horizontal aerials unsuitable.

Slant:
1. Nearly as good as vertical for cars and portables.
2. Unmodified roof-level aerials will suffer a 3 dB reduction of signal.
3. If necessary, tilting of the aerial can overcome the reduction of signal.
4. Similar service areas apply for each type of reception (stereo on fixed aerials, car reception and portables).

Circular:
1. Nearly as good as vertical for cars and portables.
2. Unmodified roof-level aerials will suffer a 3 dB reduction of signal.
3. Similar service areas apply for each type of reception.

When making similar comparisons, the results are in reasonable agreement with Spencer[1,2] except that the present investigation has shown that the residual polarization discrimination inside buildings is somewhat greater. For car reception the present work shows a more positive advantage for mixed polarization than was obtained by Vinnell[3] although not as great as in some of the tests made by Spencer.

It can be concluded that there is an advantage for existing horizontally polarized transmissions to have a vertical component added; doubling of the total power transmitted would avoid the 3 dB loss on existing external aerial installations, and would augment the advantage for mobile reception. For new stations the advantage seems to be with vertical transmission.

The consequences of adding a vertical component *of equal power* to existing horizontal transmissions, for listeners in built up areas, is to make an average improvement in the range of 5 to 7 dB both for car reception and for reception on portables in the home or office; also, there would be negligible degradation to existing installations using properly installed, horizontally polarized, out-door aerials.

Although horizontal receiving aerials should give greater discrimination against some multipath signals, we found that, in built up areas, the difference between multipath effects for vertical and horizontal polarization (using receiving aerials of the correct polarization) was not significant.

9. Acknowledgement

We acknowledge the assistance given by BBC Transmitter Capital Projects Department who loaned and installed the test transmitter and aerial system.

10. References

1. SPENCER, J.G. Band II f.m. sound broadcasting: the effects of a change to circular polarization. BBC Research Department Report No. 1969/7.

2. SPENCER, J.G. Band II f.m. sound broadcasting: field tests at Radio Nottingham using mixed polarization. BBC Research Department Report No. 1970/35.

3. VINNELL, D. The relationship of v.h.f. car radio reception quality to field strength at 10 metres. BBC Research Department Report No. 1977/45.

4. BEADLE, D.G., FOX, J.A. A field strength measuring receiver for Band II. BBC Research Department Report No. 1975/33.

5. ROBINSON, A.P. A statistical analyser for digital field strength data. BBC Research Department Report No. 1979/24.

6. THODAY, R.D.C. Experimental v.h.f. ferrite aerials for car reception. BBC Research Department Report No. 1979/28.

7. HARVEY, R.V. VHF Sound broadcasting: subjective appraisal of distortion due to multipath propagation in f.m. reception. *Proc. I.E.E.,* **Vol. 107**, Part B, No. 35, September 1960.

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